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D5000 GENERAL ELECTRICAL REQUIREMENTS

RECORD OF REVISIONS

Rev	Date	Description	POC	OIC
0	11/18/02	General revision and addition of endnotes; added nuclear requirements. Replaces Subsections 201-202, 218, 219, 295.	David W. Powell, *FWO-SEM*	Kurt Beckman, *FWO-SEM*

D5000 GENERAL ELECTRICAL REQUIREMENTS

1.0 APPLICATION OF THIS CHAPTER

A. The *National Electrical Code* (and similarly other codes and standards) contains provisions considered necessary to safety. Compliance with the applicable codes and proper maintenance of systems will result in installations that are free from hazard, BUT not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.[1] The purpose of this chapter of the LANL Engineering Manual (LEM) is to provide electrical facilities that are free from hazard AND are efficient, convenient, adequate for good service, maintainable, standardized, and adequate for future expansion of electrical use.

B. Electrical design, material, equipment, and installations shall comply with site-specific requirements in this Chapter and Chapter 1 of the LEM.[2] Where appropriate, guidance is provided to aid the cost-effective implementation of site-specific requirements and the requirements in the applicable codes. Code requirements are minimum requirements that are augmented by the site-specific requirements in this chapter.

C. Within this chapter, other than for titles of codes and standards, *italicized* text indicates provisions considered desirable but not mandatory. Recommendations are based on good business and engineering practice and lessons-learned at LANL. All other text in regular type indicates **mandatory** requirements unless prefaced with wording identifying it as guidance or recommended.

D. In addition to new electrical installations, this Chapter applies to all renovation, replacement, modification, maintenance, or rehabilitation projects for which the LANL electrical authority having jurisdiction[3] (AHJ) requires a design.[4] The LANL electrical AHJ requires a design for all projects that include any of the following elements:

1. New or modified branch circuit exceeding 100 amps.

2. Branch circuit of any size when the grounding system integrity or existing or proposed panelboard loads is unknown.

3. New or modified feeder circuit, including installation of transformer.

4. New or modified service.

E. Bring existing electrical systems and sub-systems into compliance with current codes and requirements in this chapter when renovation work includes major replacements, modifications, or rehabilitation that exceeds 50% of the estimated replacement value[5] of the existing electrical system or sub-system.[6]

1. This requirement applies on a system or sub-system basis (e.g. electrical power system, interior lighting sub-system, fire protection detection sub-system, etc.) instead of a Chapter 7-wide basis.

2. Systems and sub-systems are listed in Section 210 of Chapter 1 of the LEM.

3. Only those systems or sub-systems where major replacements, modifications, or rehabilitation exceed 50% of the estimated replacement value of the existing system or sub-system are required to be brought to into compliance with requirements in current codes and this Chapter.

4. Existing electrical systems or sub-systems which (1) have replacements, modifications, or rehabilitation which are less than 50% of the estimated replacement value of the system and (2) are deemed safe by the AHJ, may remain in service.[7]

5. Where an existing installation meets, or is altered to meet, the requirements of the current revision of a section of the LEM, such installation is considered to be in compliance with this heading and is not required to comply with any previous revision of the section.

6. Existing installations, including in-kind maintenance replacements, which currently comply with prior revisions of a section of the LEM, need not be modified to comply with the current revision, except as may be required for safety reasons by the AHJ.

F. Definitions of terms in Chapter 7 are the same as those in the National Electrical Code.

2.0 CODES AND STANDARDS

2.1 General Requirements

A. Electrical design, material, equipment, and installation shall comply with the applicable portions of the latest edition of each code and standard listed below or referenced elsewhere in this chapter, in effect at the time of design contract award, unless otherwise noted in the LANL Work Smart Standards. LANL Work Smart Standards are denoted as "WSS."

B. In many instances recommendations or "best practices' in Work Smart Standards, DOE orders, building codes, electrical codes, and industry standards have been adopted as requirements in this Chapter of the LEM.

C. If there is a conflict between codes, standards, and LANL requirements in this chapter, contact the LEM Discipline POC for assistance in resolving the conflict. If a requirement in the LEM exceeds a minimum code or standard requirement, it is not considered a conflict, but a difference.

D. Where the *National Electrical Code* (NEC) uses terms similar to "by special permission," obtain written permission from the LANL electrical AHJ[8].

2.2 Work Smart Standards (WSS)

A. LANL Environmental Health and Safety Work Smart Standards are contained in Appendix G of the University of California/DOE Contract. http://labs.ucop.edu/internet/comix/

B. Comply with the edition and addenda in effect on the effective date noted in the WSS set, unless otherwise specified. Exception: Comply with the latest edition of the CFRs. http://labs.ucop.edu/internet/app_g/wss_lanl.pdf.

C. If above links fail, obtain a copy of the WSS set from the LANL Project Leader.

2.3 LANL Documents

A. LANL Engineering Manual[9]

1. The LEM, arranged by discipline-specific chapters, provides site-specific engineering requirements and guidance for LANL facilities and systems.

2. Chapters are [being] subdivided into sections that allow for more convenient revision control of the information. Section numbering follows the UNIFORMAT system promulgated by the Construction Specifications Institute (CSI) and further described in ASTM E1557 (e.g., D5010 Electrical Service and Distribution).

3. Standard detail drawings (numbered ST-XXXXX-X) referenced in the LEM in regular type are to be considered templates that shall be used in the design drawings for specific projects. The templates shall be edited only to reflect the particular details of the project. If the engineer/designer wishes to take a variance for a portion of an applicable detail, then the LEM POC for that detail shall be contacted for concurrence.

B. LANL Construction Specification Manual

The LANL Construction Specifications Manual provides templates for the preparation of project specific construction specifications at LANL. These documents are referenced throughout the LEM. The following instructions are provided concerning their use.

- The Specification sections are numbered in accordance with the CSI MASTERFORMAT.

- Sections referenced in the LEM in regular type are to be considered guidance specifications that shall be used for establishing the specifications for specific projects. The specifications shall be edited to reflect the scope of the project. If the engineer/designer wishes to take a variance for a portion of an applicable Construction Specification, the POC for that specification shall be contacted for concurrence.

- Specification sections not referenced in the LEM or referenced in *italicized type* are to be considered guidance specifications. These specifications may be edited to suit the projects and variances may be taken at the discretion of the engineer/designer.

C. LANL Drafting Manual

The LANL Drafting Manual provides drafting requirements for use when creating or revising construction drawings for LANL construction projects.

D. The above manuals are not intended to cover all requirements necessary to provide a complete operating facility. The engineer/designer is responsible for providing a complete design package (drawings and specifications) as required to meet project specific requirements. Questions concerning the contents in these manuals should be addressed to the applicable LANL discipline POC.

E. The LANL manuals are available at http://www.lanl.gov/f6stds/pubf6stds/xternhome.html.

2.4 DOE (Department of Energy) (Selected Orders)

A. DOE O 420.1, Facility Safety

B. DOE M 440.1, *Explosive Safety Manual* (WSS)

C. DOE O 6430.1, *General Design Criteria*, Division 13, Special Facilities only (WSS)

The above DOE directives available at http://www.directives.doe.gov/serieslist.html

2.5 Building and Electrical Codes

A. *International Building Code* (IBC) (WSS). Note: In all places where the IBC refers to the *ICC Electrical Code* substitute the *National Electrical Code*. In all places where the IBC refers to the *International Fire Code* substitute the NFPA *National Fire Codes*.

B. *National Electrical Code* (NEC), NFPA 70 (follow version required by WSS, but no earlier than 2002 edition)

C. *2002 New Mexico Electrical Code* (WSS).[10] *Guidance: The 2002 "New Mexico Electrical Code" is available at http://www.nmcpr.state.nm.us/nmac/_title14/T14C010.htm, and sold by the NM Construction Industries Division (505) 827-7030.*

D. *National Electrical Safety Code* (NESC), IEEE C2 (WSS).

E. *National Fire Alarm Code*, NFPA 72 (WSS)

NOTE: For LANL personnel, many of the following national standards are available at http://lib-www.lanl.gov/infores/stand/stanihs.htm.

2.6 IEEE (Institute of Electrical and Electronics Engineers)

A. IEEE Std 141, *Recommended Practice for Electric Power Distribution for Industrial Plants* (Red Book)

B. IEEE Std 142, *Recommended Practice for Grounding of Industrial and Commercial Power Systems* (Green Book)

C. IEEE Std 241, *Recommended Practice for Electric Power Systems in Commercial Buildings* (Gray Book)

D. IEEE Std 242, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems* (Buff Book)

E. IEEE Std 315, *Graphic Symbols for Electrical and Electronics Diagrams*

F. IEEE Std 399, *Recommended Practice for Power Systems Analysis* (Brown Book)

G. IEEE Std 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications* (Orange Book)

H. IEEE Std 493, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems* (Gold Book)

I. IEEE Std 519, *Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*

J. IEEE Std 739, *Recommended Practice for Energy Management in Industrial and Commercial Facilities* (Bronze Book)

K. IEEE Std 902, *Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems* (Yellow Book)

L. IEEE Std 1015, *Recommended Practice Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems* (Blue Book)

M. IEEE Std 1100, *Recommended Practice for Powering and Grounding Electronic Equipment* (Emerald Book)

2.7 ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers)

ASHRAE/IESNA Standard 90.1, *Energy Standards for Buildings Except for Low Rise Residential Buildings*.[11]

2.8 IESNA (Illuminating Engineering Society of North America)

A. IESNA *Lighting Handbook*, Ninth Edition

B. IESNA RP-1, *American National Standard Practice for Office Lighting*.

C. IESNA RP-7, *American National Standard Practice for Industrial Lighting*.

2.9 NFPA (National Fire Protection Association)

National Fire Codes and Standards (WSS)

> **Note:** Buildings and structures designed to fully meet the requirements of NFPA-101, The Life Safety Code, shall be considered to have met the "life safety" requirements of IBC, OSHA (29 CFR 1910), and all other codes.[12]
>
> **Note:** Listing of current NFPA codes and standards are available at http://www.nfpacatolog.org

2.10 NECA (National Electrical Contractors Association)[13]

A. NECA 1, *Standard Practices for Good Workmanship in Electrical Contracting* (ANSI)

B. NECA 101, *Standard for Installing Steel Conduit (Rigid, IMC, EMT)*

C. NECA 202, *Recommended Practice for Installing and Maintaining Industrial Heat Tracing Systems* (ANSI)

D. NECA 305, *Standard for Fire Alarm System Job Practices* (ANSI)

E. NECA 400, *Recommended Practice for Installing and Maintaining Switchboards* (ANSI)

F. NECA 402, *Recommended Practice for Installing and Maintaining Motor Control Centers* (ANSI)

G. NECA/EGSA 404, *Recommended Practice for Installing Generator Sets* (ANSI)

H. NECA 407, *Recommended Practice for Installing Panelboards* (ANSI)

I. NECA/IESNA 500, *Recommended Practice for Installing Indoor Commercial Lighting Systems* (ANSI)

J. NECA/IESNA 501, *Recommended Practice for Installing Exterior Lighting Systems* (ANSI)

K. NECA/IESNA 502, *Recommended Practice for Installing Industrial Lighting Systems* (ANSI)

L. NECA/BICSI 568, *Standard for Installing Commercial Building Telecommunications Systems* (ANSI)

2.11 TIA/EIA (Telecommunications Industry Association/Electronics Industries Association)[14]

A. TIA/EIA-568-B series[15], Commercial Building Telecommunications Cabling Standard (ANSI):

1. TIA/EIA-568-B.1, *General Requirements*
2. TIA/EIA-568-B.2, *100-Ohm Balanced Twisted-Pair Cabling Standard*
3. TIA/EIA-568-B.3, *Optical Fiber Cabling Component Standard*

B. EIA/TIA-569-A, *Commercial Building Standard for Telecommunications Pathways and Spaces* (ANSI).

C. EIA/TIA-606, *Administrative Standard for the Telecommunications Infrastructure of Commercial Buildings* (ANSI).

D. TIA/EIA-607, *Commercial Building Grounding and Bonding Requirements for Telecommunications* (ANSI).

3.0 COORDINATION OF DESIGN REQUIREMENTS

3.1 General

Coordinate and clarify electrical design requirements with the FWO-SEM project engineer or the Chapter 7 Point of Contact. Coordinate and clarify National Electrical Code requirements with the LANL Electrical Authority Having Jurisdiction (AHJ).

3.2 Site Utilities

Coordinate and clarify electrical utility design requirements with the following organizations:

A. Electrical: Support Services Contractor's Utilities Electric and Steam Branch

B. Telecommunications: LANL Telecommunications Group

3.3 Special Systems

Coordinate and clarify special systems design requirements with the following organizations:

A. Life Safety: LANL Fire Protection Group

B. Fire Alarm: LANL Fire Protection Group

C. Telecommunications: LANL Telecommunications Group

D. Paging Systems: LANL Telecommunications Group

E. Badge Reader Systems: LANL Telecommunications Group

F. Security Systems: LANL Security Systems Group; Also see LEM Security Chapter (future)

4.0 DESIGN DOCUMENTATION

4.1 Calculations

A. Electrical calculations shall include, but are not limited to, the following:

1. Narrative descriptions of the calculation methods, input data sources, assumptions, and conclusions reached.
2. The source of each formula or method used is to be noted with all assumptions or exceptions listed with units defined. Provide copies of tabulated data used.
3. Equipment selection criteria, including as appropriate: voltage, current, power, frequency, impedance, operating temperature, temperature rise, altitude de-rating, and efficiency.
4. Copies of catalog sheets showing equipment performance points for all major equipment included in the systems design.

B. Calculate electrical power system design loads for sizing systems and equipment in accordance with Article 220 of the National Electrical Code. For load densities use the greater of the values in the NEC, this design standard, or the actual connected loads or measured loads. Include the effects of harmonic-generating loads. Use diversity factors only as specifically permitted by NEC or other recognized national standards. Include in feeders, services, and associated distribution equipment the capability for 20% future load growth.[16]

C. Perform fault current calculations using procedures outlined in IEEE Std. 141 and IEEE Std. 242. *Commercial software may be used if it has been benchmark tested and provides results that are consistent with results from using the IEEE procedures.*[17]

1. For medium voltage systems, obtain fault duty information from the LANL Support Services Subcontractor electrical utility.
2. For low voltage systems, base fault current calculations on an infinite bus medium voltage utility source.
3. Extend calculations to points in the low voltage distribution system where fault duty is less than 14,000 amps RMS symmetrical on 480Y/277V systems and less than 10,000 amps RMS symmetrical on 208Y/120V or 240/120V systems.

D. Perform coordination studies using procedures outlined in IEEE Std. 141 and IEEE Std. 242. *Commercial software may be used if it has been benchmark tested and provides results that are consistent with results from using the IEEE procedures.*[17] During design demonstrate that selective coordination can be achieved; determine preliminary settings for circuit breaker trip units. After switchgear construction submittals are approved, update the coordination study to show the actual equipment; determine final trip unit settings.

1. Perform protective device coordination studies for projects with a low voltage service size larger than 800 amperes.
2. Include in the coordination study all voltage classes of equipment from the utility's incoming line protective device down to, and including, each low voltage load protective device rated 100 amperes and larger.
3. Use the selective coordination time interval guidelines in Table D5000-1. Where these guidelines must be compromised, include in the study a narrative discussion of the assumptions and logic leading to the proposed compromise of selective coordination.
4. Provide tabulated circuit breaker electronic trip unit settings based on the results of the fault current study and the coordination study; include the following information for each circuit breaker electronic trip unit:
   - Circuit number
   - Load name
   - Sensor rating (amperes) "S"
   - Rating plug (amperes) "P"
   - Long time pickup setting (times P)
   - Long time delay setting (seconds)
   - Short time pickup setting, if used (times P)
   - Short time delay setting, if used (seconds)
   - Instantaneous pickup setting (times P)
   - Ground fault pickup setting (times P)
   - Ground fault delay setting (seconds)
   - Trip unit manufacturer and model

- Remarks (i.e. i^2t setting, etc.)

TABLE D5000-1, SELECTIVE COORDINATION TIME INTERVAL GUIDELINES

	INDUCTION RELAYS	SOLID-STATE RELAYS
1. RELAY-TO-DOWNSTREAM RELAY:		
CB opening time (5 cycles)	0.083	0.083
Relay over-travel	0.100	0.000
Safety Margin	0.200	0.200
Minimum time interval (seconds)*	0.383	0.283
2. RELAY-TO-DOWNSTREAM RELAY WITH INSTANTANEOUS UNIT:		
CB opening time (5 cycles)		
Relay over-travel	0.083	0.083
Safety Margin	0.100	0.000
Minimum time interval (seconds)*	0.100	0.100
	0.283	0.183
3. RELAY-TO-DOWNSTREAM LOW VOLTAGE CIRCUIT BREAKER:		
Relay over-travel	0.100	0.000
Safety Margin	0.100	0.100
Minimum time interval (seconds)*	0.200	0.100
4. RELAY-TO-DOWNSTREAM MEDIUM VOLTAGE FUSE:		
Relay over-travel		
Safety Margin	0.100	0.000
Minimum time interval (seconds*)	0.100	0.100
(To total clearing time curve)	0.200	0.100
5. RELAY-TO-DOWNSTREAM LOW VOLTAGE FUSE		
Relay over-travel	0.100	0.000
Safety Margin	0.100	0.100
Minimum time interval (seconds)*	0.200	0.100
(To total clearing time curve)		
6. MEDIUM VOLTAGE FUSE-TO-DOWNSTREAM PROTECTIVE DEVICE: For times greater than 0.01 second, the total clearing time of the downstream protective device should be below and to the left of the adjusted minimum-melting curve of the upstream fuse. The minimum melting curve of the upstream fuse should be adjusted to 75% (current basis) to compensate for pre-fault loading. AND For times less than 0.01 second, the total clearing energy of the downstream fuse should be less than the minimum melting energy of the upstream fuse.		
7. LOW VOLTAGE CIRCUIT BREAKER-TO-DOWNSTREAM CIRCUIT BREAKER: Time-current characteristic bands should not cross or overlap. OR The maximum available fault current at the downstream circuit breaker is less than the instantaneous trip setting of the upstream circuit breaker.		
8. LOW VOLTAGE FUSE-TO-DOWNSTREAM LOW VOLTAGE FUSE: The total clearing time of the downstream fuse should be below and to the left of the minimum-melting curve of the upstream fuse.		
9. NOTES: * Time intervals may be decreased if field tests indicate that the system still selectively coordinates using the decreased time interval. When protecting a delta-wye substation or pad mounted transformer, add an additional 16% current margin between the primary and secondary protective device curves. Refer to IEEE Std. 242 for additional system protection and selective coordination guidelines.		

E. Refer to other system elements (e.g. lighting, grounding, etc.) for additional electrical calculation requirements pertaining to those system elements.

4.2 Drawings

A. Provide a complete drawing package as required to meet project specific requirements.

B. Drawing set composition, organization, and format shall comply with the LANL Drafting Manual.

C. Use Electrical Drawing ST-D5000-1 for electrical symbols. Delete the general notes on projects that have construction specifications.

D. Use Electrical Drawing ST-D5000-2 as a template for the project electrical one-line diagram. Edit the template to meet project specific requirements. Use additional sheets as required for large systems.

1. A one-line diagram as described in this section shall be used to represent the electrical power service and distribution system for each facility. The one-line shall show the electrical distribution system from the service point down to the lighting/power panelboard and motor control center level.
2. One-Line size, drafting layers and software shall be in accordance with the LANL Drafting Manual. One-Line diagrams shall be formatted as depicted in LANL Standard Drawing ST-D5000-2.
3. The One-Line shall be configured such that upstream to downstream paths are shown from top to bottom or left to right.
4. One-Line symbols shall be in accordance with the LANL Drafting Manual and the standard legend and symbols provided in LANL Standard Drawing ST-D5000-1.
5. LANL Standard Drawing ST-D5000-1 and ST-D5000-2 shall be followed for the consistent layout and application of symbols.
6. Any equipment to be included in a one-line that is not reflected in the LANL standard drawings shall be depicted in accordance with IEEE Std 315.
7. One-line diagrams shall include the following information as applicable:
   - **Utility source(s):** Utility circuit voltage, circuit number(s), riser pole number(s), pad-mounted switchgear cubicle number(s), and manhole structure number(s).
   - **Supply characteristics:** Service point nominal system voltages (13.2 kV, 480Y/277 V, 208Y/120V, 120/240 V), system configurations (wye or delta, grounded or ungrounded), frequency (if other than 60 Hz), phase rotation (if other than NEC standard), short-circuit current (3-phase, RMS symmetrical amperes).
   - **Power transformers**: Ratings (kVA, primary voltage, secondary voltage, and percent impedance), cooling methods (e.g. OA/FA), winding connections, grounding electrode conductor size, dielectric type, location.
   - **Generator systems:** Ratings (voltage, kW/kVA), connection, fuel type, transfer switch ratings, equipment code, and location.

- **Major distribution equipment (e.g. unit substations, switchgear, switchboards, panelboards):** Equipment code, location (room number), ratings (voltage, frequency if other than 60 Hz, amperes, connection type), short-circuit interrupting rating, types of loads served.
- **Service and feeder switching and overcurrent protective devices:** Circuit number, number of poles (if other than three poles), switch or circuit breaker frame size in amperes, circuit breaker long-time trip amperes, circuit breaker ground-fault trip amperes, fuse rating and type, short-circuit interrupting rating. Provide this same information for branch circuits that are shown on the one-line diagram.
- **Protective relays:** Function, use, type, and number. Use device function numbers from IEEE C37.2.
- **Services and feeders:** Raceway size and length. Quantity, size, type (if other than copper), and insulation type for phase, grounded, and equipment grounding conductors. Provide the same information for branch circuits that are shown on the one-line diagram.
- **Metering:** Voltmeters, ammeters, kW/kWh meters, test blocks, electronic metering packages.
- **Potential transformers**: Number, ratio, and overcurrent protection
- **Current transformers:** Number and ratio.
- **Dry-type transformers:** Ratings (kVA, K-factor, primary voltage, secondary voltage, and percent impedance), cooling methods (e.g. OA/FA), temperature rise, winding connections, location, grounding electrode conductor size.
- **Surge protective devices:** Indicate surge protective devices for medium-voltage equipment, low-voltage service equipment, and specialized systems (e.g. isolated ground power systems).
- **Major loads:** [18] Voltage, kVA rating, and location of all branch circuit loads rated 100 amperes and greater and all loads connected to switchboards or switchgear assemblies.
- **Motors:** Voltage, horsepower or kVA rating, starting method if other than across the line, and location of all motors connected to switchgear and switchboards. *Motors connected to motor control centers or panelboards are branch circuit loads; they can be shown either on one-line diagrams or included in schedules; consult with the Facility Manager or the User for preference.*
- **Available short-circuit current:** The calculated three-phase bolted short-circuit current at each bus down to points in the low voltage distribution system where fault duty is less than 14,000 amps RMS symmetrical on 480Y/277V systems and less than 10,000 amps RMS symmetrical on 208Y/120V or 240/120V systems.
- **Critical systems:** Indicate critical loads (e.g. safety class or safety significant, emergency power systems, standby power systems).

- **Service Load Summary:** Provide a summary of the calculated or measured load for the service entrance. Refer to Drawing ST-D5000-2 for the required content and format.

E. Use Electrical Drawing ST-D5010-1 as a template for the project grounding diagram. Edit the template to meet project specific requirements.

F. Use Electrical Drawing ST-D5010-2 as a template for the project isolated ground system diagram(s) (if present). Edit the template to meet project specific requirements.

G. Use Electrical Drawing ST-D5030-1 as a template for the project telecommunications system riser diagram(s) and telecommunications room plan(s). Edit the template to meet project specific requirements.

H. Use Electrical Drawing ST-D5030-2 as a template for the project fire alarm system riser diagram and input-output matrix. Edit the template to meet project specific requirements.

I. Use Electrical Drawing ST-D5000-3 as a template for the project circuit designations and electrical equipment identification. Edit the template to meet project specific requirements.

J. Use Electrical Drawing ST-D5020-1 as a template for the project motor control diagrams. Edit the template to meet project specific requirements.

4.3 Construction Specifications

A. Provide a complete specification package as required to meet project specific requirements.

B. Specification set composition, organization, and format shall comply with the LANL Construction Specification Manual.

C. Edit the applicable LANL construction specification sections to meet project specific requirements: refer to paragraph 2.3-B of this Section.

D. Generate additional construction specification sections as required to describe project materials or systems not addressed in the LANL construction specification sections.

4.4 Sealing Construction Documents

Comply with the New Mexico Engineering and Surveying Practice Act (Chapter 61, Article 23 NMSA 1978). All electrical drawings, specifications, calculations, or reports prepared by consultants or contractors that are involved in the practice of engineering shall bear the seal and signature of a professional engineer, currently licensed in New Mexico, in responsible charge and directly responsible for the electrical engineering work.[19]

5.0 SYSTEM REQUIREMENTS

5.1 Working Spaces

A. Use only the inch-pound dimensions in the text and tables in NEC Article 110 to determine safety-related working spaces, minimum distances, and elevations.[20]

B. Where a negative impact on safety would result, hard conversion from inch-pound units to metric units shall not be permitted.

5.2 Energy Conservation

Comply with ASHRAE Standard 90.1.

5.3 Sustainable Design

Electrical systems design, materials, and construction are an integral component of sustainable building design. Design electrical systems and specify equipment for compatibility with the building and site aesthetics, mechanical systems requirements, and indoor environmental quality requirements to assure multi-disciplined whole building sustainable design practices are followed.

5.4 Standards for Material and Equipment

A. Use electrical materials and equipment that is constructed and tested in accordance with the standards of NEMA, ANSI, ASTM, or other recognized commercial standard.

B. If material and equipment is labeled, listed, or recognized by any Nationally Recognized Testing Laboratory (NRTL) acceptable to OSHA and the LANL Electrical AHJ, then provide NRTL labeled, listed, or recognized material and equipment.[21] Acceptable Nationally Recognized Testing Laboratories include[22]:

- Underwriters Laboratories, Inc. (UL)
- Factory Mutual Research Corp. (FMRC)
- Intertek Testing Services NA, Inc. (ITSNA, formerly ETL)
- Canadian Standards Association (CSA)

A complete listing of **acceptable** NRTLs is located at http://www.osha-slc.gov/dts/otpca/nrtl/index.html.

C. Where material and equipment is not labeled, listed, or recognized by any NRTL, provide a manufacturer's Certificate of Compliance indicating complete compliance of each item with applicable standards of NEMA, ANSI, ASTM, or other recognized commercial standard.

D. Do not install or use electrical material or equipment for any use other than that for which it was designed, labeled, listed, or identified unless formally approved for such use by the LANL Electrical AHJ.[23]

5.5 Operating Altitude

Provide electrical equipment that is suitable and rated (or properly de-rated) for operation at an elevation of not less than 7500 feet.[24] *The reduced air pressure at this elevation impedes equipment cooling and reduces the electrical insulation properties of air.* NOTE: Some LANL facilities such as TA-16 and Fenton Hill are at elevations higher than 7500 feet; provide equipment suitable for use at the elevation of such sites.[25]

5.6 Lightning

A. Provide systems protected from the effects of direct or nearby lightning discharges in accordance with NFPA 780, IEEE Std 1100, and the IEEE C62 Surge Protection Standards Collection. *In an average year Los Alamos experiences 61 thunderstorm days a year, about twice the national average.[26] The lightning flash density for parts of LANL is 8 flashes to ground per sq km per year.[27]*

5.7 Power System Reliability

Power system reliability consideration shall comply with IEEE 493 to ensure continual power supply to systems and equipment designated by project design criteria as “mission critical,” “safety significant,” or “safety class.” Consider the need for multiple transformer-switchgear service equipment to ensure power supply continuity within the facility during scheduled or emergency equipment outages.[28]

5.8 Power System Harmonic Limits

Limit harmonic currents at the point of service for each building to comply with IEEE Std 519.[29]

5.9 Adequacy and Future Expansion

Provide electrical systems with adequate capacity for the initial known requirements plus not less than 20 percent future expansion of the system.

5.10 Fault Current Capacity

Provide low-voltage power switchgear assemblies, switchboards, and panelboards with bus bracing and device interrupting capacities that exceed the fault current available at the terminals.

5.11 Selective Coordination

A. Provide selectively coordinated overcurrent protection for service, feeder, and branch-circuit overcurrent devices.

B. When the NEC requires ground-fault protection for service or feeder disconnecting means, provide an additional step of ground fault protection in the next level of feeders as required to provide fully selectively coordinated ground-fault protection.

5.12 Power Quality

A. Provide electrical systems that are selected and configured to provide adequate power quality for the satisfactory operation of electrical utilization equipment:

- *The highest practical service, distribution, and utilization voltages should be used.*
- *High-impact electrical loads such as HVAC equipment, elevators, and process loads should be segregated on separate feeders from sensitive loads.*
- *Step-down transformers and associated panelboards should be located physically close to the loads that they serve.*
- *Loads on each feeder should be balanced so the voltage on each phase will be within 1 percent of the average voltage of the three phases.*[30]

B. Follow recommended practice in IEEE Std 1100 and IEEE Std 141.

6.0 EQUIPMENT LOCATION

6.1 General

A. Locate electrical equipment so it will be accessible for inspection, service, repair, and replacement without removing permanent construction, with working clearance and dedicated space as required by the NEC and as recommended by the manufacturer.[31]

B. Locate equipment so generator exhaust, etc. does not enter occupied spaces through outside air intakes.

C. Select sites carefully when locating equipment outside on grade. Ensure that factors such as snow accumulation and drift, ice, windy areas, rainwater from roof overhangs, etc., do not affect equipment performance and maintenance. *Avoid locations on the north side of the building.*

D. Locate equipment to minimize noise and sound vibration transmission to occupied areas of the building.

E. Locate any portion of roof mounted electrical equipment a minimum of 10 feet from the edge of roof or inside face of parapet. If the distance is less than 10 feet, specify a 42-inch-high restraint, e.g., guard rails, parapet, screen wall, etc.[32]

6.2 Equipment Rooms and Spaces

A. Provide one or more dedicated electrical equipment rooms or dedicated electrical equipment spaces on each floor in every building except for modifications where loads can be served from existing equipment.[33]

1. Provide electrical equipment rooms to house switchgear, switchboards, power panelboards, transformers, transfer switches, lighting control relay panels, and similar distribution equipment in office buildings or light laboratory buildings.

2. *Dedicated electrical equipment spaces may be used in lieu of equipment rooms for switchgear, panelboards, transformers, transfer switches, lighting control relay panels, and similar distribution equipment in industrial, process, or production buildings.*

3. *In laboratory buildings, one or more panelboards dedicated to each laboratory may be located in the corridor outside the lab entrance door. Recess lab panelboards in public corridors. Lab panelboards may be surface mounted in non-public service corridors.*

4. *In existing buildings where no other suitable location is available, and with the consent of the LANL Electrical Authority Having Jurisdiction, panelboards may be recess mounted in corridors.*

B. Design electrical equipment rooms or spaces to facilitate equipment installation/removal and to provide adequate access for operation and maintenance of the equipment.

C. Make provisions for the removal of the largest component from each electrical room or space for off-site servicing. Provide adequate floor loading capability on the access routes and in the electric rooms or spaces for the electrical equipment and material handling equipment.[34]

D. Locate electrical rooms or spaces in the building to satisfy the following criteria:

1. Maximum feeder voltage drop: 2 percent[35]
2. Maximum branch circuit voltage drop: 3 percent [35]
3. Maximum 208Y/120V system branch circuit length: 100 ft[36]
4. Maximum 480Y/277V system branch circuit length: 230 ft[37]
5. Electric rooms or spaces vertically aligned in multi-story buildings[38]
6. Branch circuit panelboards on the same floor as the loads they serve[39].

E. For indoor installations provide not less than 60 inches of clear height to the underside of the building structure above medium-voltage switchgear to allow for vertical conduit elbows above the equipment.[40] For indoor installations provide not less than 48 inches of clear height to the underside of the building structure above low-voltage switchgear and switchboards to allow for busway transitions and conduit bends above the equipment.[41]

F. For indoor installations of medium-voltage switchgear, provide access aisles not less than 5'-0" in front, 5'-0" in rear (if rear access is required)[42], and 3'-0" at ends of equipment after providing space for future expansion.[43] For indoor installations of low-voltage, drawout switchgear assemblies, provide access aisles not less than 4'-6" in front[44], 3'-6" in rear[45], and 3'-0" at ends of low-voltage equipment after providing space for future expansion. Provide greater access space if recommended by the manufacturer or if required to fully open access doors.

G. For new construction, provide dedicated electrical space equal to width and depth of the equipment extending from floor to a height of 25 ft or to the structural ceiling; allow no piping, ducts, or equipment foreign to the electrical installation in this zone. For work in existing structures, follow Article 110 in the 2002 NEC. [46]

H. Medium-voltage electrical equipment rooms within buildings shall have a minimum fire resistance of 3 hours.[47]

I. Provide electrical equipment room doors that open in the direction of exit travel and are equipped with panic hardware.[48]

J. Provide not less than 30 footcandles[49] general illumination on the vertical surfaces of the electrical equipment. Provide similar illumination at the rear of freestanding equipment. Provide emergency illumination to avoid safety problems and to facilitate trouble-shooting during a power outage.[50]

K. Provide at least one general-purpose receptacle in each electric room or space for power tools and supplemental lighting.[51]

L. Provide HVAC for electrical distribution equipment spaces with 30 percent air filtration and heating/cooling as required to maintain an average ambient temperature not to exceed 86ºF (30ºC). The average ambient temperature shall cover 24 hours, and the maximum temperature during the 24-hour period shall not exceed 104ºF (40ºC).[52]

M. If possible, locate electrical service equipment in above-grade areas not subject to flooding. If service switchgear must be installed below grade, provide redundant sump pumps supplied from a reliable standby power system.[53]

N. Locate electrical service entrance equipment as close as practical to the building water service entrance and to major electrical loads.

O. Avoid installing panelboards, transformers, etc. in corridors, stairways, or janitor closets.

7.0 ELECTRICAL IDENTIFICATION

7.1 Component Identification

A. Identify electrical equipment on drawings and tags in accordance with LEM, Chapter 1, Section 230, Component Nomenclature.[54]

7.2 Electrical Component Identification Tags

A. Comply with LANL Construction Specifications Section 16195, Electrical Identification for electrical identification products, materials, and installation.

B. Use materials and attachments suitable for the environment in which the identification will be installed.

C. Refer to Electrical Drawing ST-D5000-3 for preferred locations of electrical identification.

D. Install electrical component identification tags (formerly called code tags) to identify electrical equipment using the System Designation, Equipment Identification, the Tech Area Number, and the Building Number.[55]

E. Make identification tags using black 48 point letters on a 2 in x 3 in yellow background.[56]

7.3 Equipment Nameplates

A. Install electrical equipment nameplates of the following three categories:

1. Category I - Circuit Directory Information: Nameplates shall contain circuit number, piece of equipment being served or being served from, location of equipment served or being served from, voltage, number of phases, and number of wires.[57]
2. Category II - General or Operational Information: Nameplates shall contain basic instructions or specific operating procedures such as special switching procedures for a load transfer scheme.[58]
3. Category III - Emergency Operations: Nameplate shall contain information concerning emergency shutdown procedures for room, equipment, and building isolation in event of fire or other emergency.[59]

B. Make electrical equipment nameplates with 10 point (minimum) lettering as follows[60]:

4. Category I: White or black letters on a (minimum) 1 inch x 2½ inch blue background.
5. Category II: White letters on a black background, size as required for instructions.
6. Category III: White or black letters on a red background, size as required for emergency instructions.

7.4 Voltage Markers

Install voltage markers that conform to OSHA regulations on switchgear, transformers, motor control centers, panelboards, starters, safety switches, pull boxes, and cabinets.[61]

7.5 Warning Signs

Install warning signs that conform to OSHA and NEC danger and caution specifications on switchgear, switchboards, transformers, motor control centers, panelboards, starters, safety switches, busways, pull boxes, and cabinets.[62]

7.6 Arc-Flash Warning Labels

Install arc-flash warning labels on switchgear, switchboards, transformers, motor control centers, panelboards, starters, and safety switches.[63]

7.7 Emergency System Identification

Install markers to identify emergency system transfer switches, generators, switchgear, transformers, motor control centers, panelboards, starters, safety switches, pull boxes, and cabinets as components of the emergency system.[64]

7.8 Outlet Labels

Install labels on receptacle outlets and light switches indicating circuit number, panelboard, and voltage.[65]

7.9 Wire Markers

Install wire markers on power, control, instrumentation, fire alarm, and communications circuit wires.[66]

7.10 Working Space Markers

Permanently mark the NEC required clear space in front of and behind switchgear, transformers, motor control centers, panelboards, starters, and safety switches. Install marking on the floor using color schemes conforming to ANSI Z535.1: black and white striped border. *Rear clear working space is required for maintenance activities such as thermographic inspection of energized switchgear*.[67]

7.11 Diagrams and Operating Instructions

Post and maintain diagrams, operating instructions and emergency procedures for electrical systems and major equipment. *They should consist of simplified instructions and diagrams of equipment, controls and operation of systems, including selector switches, main-tie-main transfers, ATS-bypass, UPS-bypass etc*. Post and maintain an up-to-date one-line diagram of the electrical system adjacent to the service entrance equipment.[68]

8.0 ELECTRICAL SUPPORTS AND ANCHORAGE

A. Install supports and anchorage for electrical equipment in accordance with the NEC, manufacturer’s instructions, and LEM Chapter 5, Structural. Use appropriate hangers, supports, anchors, braces, concrete bases, sleeves, inserts, seals, and associated fastenings.

B. Support and anchorage requirements for electrical components are a function of the natural phenomena hazard (NPH) performance category (PC) level that is assigned to that component. The NPH PC level is generally higher for safety class and safety-significant components, however, a higher NPH PC level may be assigned to systems that are mission critical. Consult with the LANL Structural POC and/or Project Leader for support and anchorage requirements.

   1. For PC-1 and PC-2 components, the design of supports and anchorage shall generally follow the requirements of the International Building Code, latest edition/supplements.
   2. For PC-3 and PC-4 components, the design of supports and anchorage shall follow the requirements of DOE-STD-1020 and the LEM Structural Chapter (V).

C. The design values published as manufacturer’s allowable values for anchor bolts and pre-manufactured supports may be used provided that they are set at 98% exceedance values.

D. Refer to the following LANL Standards for additional requirements:

   1. LEM, Structural Chapter.
   2. LANL Construction Specification Section 13085, *Seismic Protection*.[69]
   3. Construction Specifications Section 16190, *Supporting Devices* for materials and installation methods.

4. The heading "Additional Requirements for Nuclear Facilities" in this Section for special requirements and guidance.

9.0 RODENT-PROOFING[70]

A. Purchase and install outdoor low-voltage and medium-voltage equipment to be rodent proof with maximum 1/4 inch[71] unprotected openings in enclosures.

B. Seal all cable entries and plug unused conduits entering outdoor equipment with material that rodents will not be able to gnaw through, squeeze through, or push aside. *Suitable materials include 24-gauge or heavier galvanized sheet steel, 19-gauge galvanized woven/welded 1/4" mesh hardware cloth, 16 to 19-gauge stainless steel 1/4" mesh hardware cloth, and galvanized lath screen.*[72]

C. When penetrating an exterior wall, roof, or floor for the passage of conduits, wireways, busducts, etc., seal opening and provide a metal collar securely fastened to the structure.[72]

D. Seal all cable entries and plug unused conduits entering indoor equipment from outdoors with material that rodents will not be able to gnaw through, squeeze through, or push aside. *Suitable materials include 24-gauge or heavier galvanized sheet steel, 19-gauge galvanized woven/welded 1/4" mesh hardware cloth, 16-19-gauge stainless steel 1/4" mesh hardware cloth, and galvanized lath screen.* [72]

10.0 DEMOLITION

A. Remove abandoned electrical distribution equipment, utilization equipment, outlets, wiring, raceway systems, and cables back to the source panelboard, switchboard, switchgear, communications closet, or cabinet.[73] *Abandoned wiring and raceways can result from actions that include the following:*

- *Equipment is removed or relocated.*
- *Fixtures are removed or relocated.*
- *System is no longer used.*
- *There is no demonstrable near term future use for the existing circuit or raceway system.*

Unused electrical equipment should only be left in place if one or more of the following conditions exist:

- *The system is in a radiological contaminated area and ALARA precludes the removal.*
- *The removal requires the demolition of other structures or equipment that are still in use. An example is conduit embedded in walls or ductbanks.*
- *The cost of removal is excessive due to hazards, construction methods, or restricted access.*

B. Remove conduits, including those above accessible ceilings, to the point that building construction, earth, or paving covers them. Cut conduit beneath or flush with building construction or paving. Plug, cap, or seal the remaining unused conduits. Install blank covers for abandoned boxes and enclosures not removed.[74]

C. Extend existing equipment connections using materials and methods compatible with the existing electrical installation and Chapter 7 of the LEM.

D. Restore the original fire rating of floors, walls, and ceilings after electrical demolition.[75]

E. Use approved lock-out/tag-out procedures to control hazardous energy sources. Assure that an electrically safe work condition exists in the demolition area before beginning demolition.[76] Where possible, disconnect the building from all sources of electrical power before beginning demolition; if this is not possible, contact the LANL electrical AHJ for planning and operational support of electrical safety during demolition.[77]

11.0 ACCEPTANCE TESTING

11.1 General

A. Perform acceptance testing, inspection, and calibration to assure that installed electrical systems and equipment, both contractor and user supplied, are:

- Installed in accordance with design documents and manufacturer's instructions,
- Ready to be energized, and
- Operational and within industry and manufacturer's tolerances.

B. Perform electrical acceptance testing, inspection, and calibration in accordance with NETA ATS–Acceptance Testing Specifications.[78]

- The testing agency must be an independent organization that can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installers of equipment or systems being evaluated by the testing agency.
- The testing agency shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.
- Electrical Testing Technicians must be certified in accordance with NETA ETT-2000 (ANSI).[79]

C. Energize electrical systems only after they have been inspected and tested in accordance with this section and have been inspected and approved by the LANL electrical AHJ.[80]

D. Perform electrical acceptance testing, inspection, and calibration using the services of the LANL Support Services Sub-contractor (if qualified) or a qualified independent electrical testing firm.

11.2 Large Projects

A. Perform electrical acceptance testing, inspection, and calibration for large, complex projects using LANL Construction Specifications Section 16950–*Electrical Acceptance Testing*.

B. *Guidance: Use the following criteria to determine if specification Section 16950 should be used:*

- *Electrical supply is 1600A or larger.*
- *Ground fault protection is present on service or feeders.*
- *The project includes complex equipment such as unit substations, switchgear, or large motor control centers.*
- *The project includes any motor 100 hp or greater.*
- *The project is in a nuclear facility.*

11.3 Small Projects

A. Perform electrical acceptance testing, inspection, and calibration for smaller, projects using LANL Construction Specifications Section 16951–*Electrical Acceptance Testing*.

B. Use specification Section 16951 for projects with service size smaller than 1600A that do not include complex equipment such as unit substations, switchboards, large motor control centers, or large motors.

12.0 SPECIAL REQUIREMENTS FOR NUCLEAR FACILITIES

A. *Guidance: The Documented Safety Analysis (DSA, formerly SAR)) is typically developed in accordance with DOE-STD-3009-94, "Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports".[81] Additional design requirements may be necessary for facilities handling hazardous materials or nuclear materials subject to the requirements of DOE O 420.1, "Facility Safety". Detailed application of these additional requirements are guided by the DSA that establishes the identification and functions of the safety (safety class and safety significant) systems, structures, and components (SSCs), and establishes the significance to safety of the functions performed by those SSCs.*

B. Use the additional guidance provided in DOE G 420.1-1, "Implementation Guide for Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria" in the design of electrical systems for Hazard Category 2 and 3 facilities.[82] *Note: DOE-STD-1027 interprets Hazard Category 1 facilities as "Category A" reactors, none of which are anticipated at LANL.* The following paragraphs interpret the DOE G 420.1-1 guidance for application at LANL.

C. Design Hazard Category 2 and 3 facilities to minimize the need for active safety-class and safety-significant SSCs. Use a multi-discipline approach with appropriate safety margins to design passive safety features that will survive the design basis accident conditions and provide defense in depth to both on-site workers and the off-site public. *Safety-class electrical power systems should not be necessary in properly designed Hazard Category 2 and 3 facilities.*

D. Design the electrical system to perform all safety functions with the reliability required by the *DSA*:

- Design **safety-class** electrical power systems against single-point failure in accordance with the criteria, requirements, and design analysis identified in ANSI/IEEE 379, "Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems".[83]
- For **safety significant** electrical power systems, analyze the need for redundant power sources (normal or alternative) on a case-by-case basis. *Redundancy may not be needed for safety-significant electrical power systems if it can be shown that there is sufficient response time to provide an alternative source of electrical power.*[84]

E. Use environmental qualification to ensure that **safety-class** SSCs can perform all safety functions, as determined by the *DSA*, with no failure mechanism that could lead to common cause failures under postulated service conditions.[84] Use the requirements for "mild environmental qualification" from IEEE 323 unless the environment in which the SSC is located changes significantly because of the design basis accident conditions. Qualification for mild environments shall consist of two elements:

- Ensuring that all equipment is selected for application to the specific service conditions based on sound engineering practices and manufacturers' recommendations.
- Ensuring that the system documentation includes controls that will preserve the relationship between equipment application and service conditions.

F. Meet the quality assurance requirements of 10 CFR 830.120 for safety SSCs for nuclear facilities. *In most cases, safety-significant SSCs used in DOE nonreactor nuclear facilities will be "off the shelf"; that is, they will not be subjected to the rigorous Nuclear Quality Assurance (NQA)-1-based requirements for "nuclear-grade" components. Therefore, safety-significant SSC quality standards can either be design-based or achieved through testing, vendor control, and inspection. However, the requirements of 10 CFR 830.120 still apply.*

G. Address the applicable IEEE Standards for safety SSCs for nuclear facilities. *For the commercial nuclear industry, multitudes of IEEE Standards define the requirements for the manufacture, installation, and testing of reactor Safety Class 1E electrical systems and components. These reactor Safety Class 1E requirements may not be directly applicable to the safety-class category defined for nonreactor nuclear facilities. These IEEE standards, however, contain useful and significant information that should be considered. Table D5000-2 lists IEEE standards that shall be addressed for safety-significant and safety-class electrical systems, keeping in perspective the applicable use of IEEE standards for Class 1E components. Before using these standards, their applicability to the design(s) being considered should be reviewed.*[84]

Table D5000-2 Recommended IEEE Standards for Nuclear Facilities[85]

This table lists standards that may not have been invoked elsewhere in Chapter 7. These additional standards shall be addressed for safety-significant and safety-class electrical systems, keeping in perspective the applicable use of IEEE standards for the specific application.	Safety Significant Systems	Safety Class Systems
IEEE C37, *Standards Collection: Circuit Breakers, Switchgear, Substations, and Fuses*	x	x
IEEE 80, *Guide for Safety in AC Substation Grounding*	x	x
IEEE 308, *Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations*		x
IEEE 323, *Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*		x
IEEE 334, *Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations*		x
IEEE 336, *Standard Installation, Inspection and Testing Requirements for Power, Instrumentation, and Control Equipment at Nuclear Facilities*	x	x
IEEE 338, *Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems*		x

ANSI/IEEE 344, *Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations*		x
IEEE 379, *Standard Application of the Single-Failure Criterion to Nuclear Power Generating Safety Systems*		x
IEEE 381, *Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations*		x
IEEE 382, *Standard for Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants*		x
IEEE 383, *Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations*		x
IEEE 384, *Standard Criteria for Independence of Class 1E Equipment and Circuits*		x
IEEE 420, *Standard for the Design and Qualification of Class 1E Control Boards, Panels, and Racks Used in Nuclear Power Generating Stations*		x
IEEE 450, *Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*	x	x
IEEE 484, *Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*	x	x
IEEE 535, *Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations*		x
IEEE 577, *Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations*	x	x
IEEE 628, *Standard Criteria for the Design, Installation, and Qualification of Raceway Systems for Class 1E Circuits for Nuclear Power Generating Stations*		x
IEEE 649, *Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations*		x
IEEE 650, *Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations*		x
IEEE 603, *Standard Criteria for Safety Systems for Nuclear Power Generating Stations*		x
IEEE 690, *Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Systems*		x
IEEE 833, *Recommended Practice for the Protection of Electric Equipment in Nuclear Power Generating Stations from Water Hazards*	x	x
IEEE 934, *Standard Requirements for Replacement Parts for Class 1E Equipment in Nuclear Power Generating Stations*		x
IEEE 944, *Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations*	x	x
IEEE 946, *Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations*	x	x

ENDNOTES:

1 National Electrical Code, 1999 Edition, Article 90-1 describes the purpose of the code.

2 LANL LIR 220-03-01.1, "LANL Engineering Manual" is the implementation requirement document for this manual. Refer to Sections 2.0 and 3.0 for statements of the purpose, scope and applicability of the LEM.

3 LANL LIR 402-600-01.1, "Electrical Safety," establishes the LANL Electrical Safety Committee as the site-wide electrical authority having jurisdiction (AHJ). The Electrical Safety Committee delegates the day-to-day AHJ duties to the LANL Chief Electrical Safety Officer.

4 E-mail from Terry Fogle (LANL Chief Electrical Safety Officer) dated 13 October 1999 established criteria for when the LANL electrical AHJ requires an electrical design for LANL projects.

5 Replacement value determined using recognized cost estimating procedures and a national material and labor cost database.

6 This exceeds requirements in the NEC or IBC but is necessary to assure that significant renovations to a facility are more than just skin deep. Over time this requirement will bring about upgrades to the underlying electrical systems in facilities.

7 Minutes from the Engineering Manual Technical Review Board meeting on 7/19/00.

8 LANL LIR 402-600-01.1, "Electrical Safety," paragraph 5.6 indicates that the Chief Electrical Safety Officer will issue clarifications and interpretations and approve alternate methods to the NEC, NESC, and the LANL Electrical Safety Program.

9 LIR 220-03-01.1 invokes the LANL Engineering Manual.

10 The WSS requires that LANL follow New Mexico Regulations: "Requirements of applicable federal, state, and local laws and regulations that address environment, safety, and health." The State of New Mexico follows the 2002 National Electrical Code with certain exceptions. The 2002 New Mexico Electrical Code describes the exceptions and additions to the 2002 Edition of the NEC.

11 ASHRAE Standard 90.1 was developed as a result of an ASHRAE and DOE jointly formed committee (Special Project 41) and it complies with the mandatory energy conservation performance criteria standards for federal buildings (10CFR435). Also, the Federal Energy Policy Act of 1992 requires States to adopt ASHRAE Standard 90.1.

12 LIR 402-910-01, *LANL Fire Protection Program*.

13 The NECA *National Electrical Installation Standards* define a minimum baseline of Quality and workmanship for installing electrical products and systems. They are intended to be referenced in contract documents for electrical construction projects.

14 The TIA/EIA telecommunications standards provide minimum requirements for wiring, pathways and spaces, grounding, and administration of telecommunications systems in commercial buildings. These standards were invoked for all federal buildings by FIPS PUB 174, 175, and 176.

15 The TIA/EIA-568-B series has replaced TIA/EIA-568-A dated October 6, 1995. The new Standard incorporates and updates the technical content of the following documents

- TSB67, *Transmission Performance Spec for Field Testing of UTP Cabling System*
- TSB72, *Centralized Optical Fiber Cabling*
- TSB75, *Additional Horizontal Cabling Practices for Open Offices*
- TSB95, *Additional Transmission Performance Guidelines for 4-pair Category 5 Cabling*
- TIA/EIA-568-A-1, *Propagation Delay & Delay Skew*

- TIA/EIA-568-A-2, *Connections & Additions to TIA/EIA-568-A*
- TIA/EIA-568-A-3, *Addendum No. 3 to TIA/EIA-568-A*
- TIA/EIA-568-A-4, *Production Modular Cord NEXT Loss Test Method and Requirements for UTP*
- TIA/EIA-568-A-5, *Transmission Performance Specifications for 4-pair Category 5e Cabling*
- TIA/EIA/IS-729, *Technical Spec for 100 Ohm Screened Twisted-Pair Cabling*

16 Twenty percent future load growth requirement is from IEEE Std. 141-1993, paragraph 2.4.1.4. Assumptions: 1% annual load growth, 20-year life.

17 Refer to 5.3.3 in IEEE Std 399.

18 The one-line diagram is generally not intended to show branch circuits; however, information about major loads and large branch circuits increases the usefulness of the diagram.

19 The WSS requires that LANL follow New Mexico Regulations: "Requirements of applicable federal, state, and local laws and regulations that address environment, safety, and health." The New Mexico Engineering and Surveying Practice Act, paragraphs 61-23-3.E, 61-23-21, and 61-23-22 define the practice of engineering and establish qualification and performance requirements for registered professional engineers as a matter of public safety.

20 The metric dimensions in Table 110.26(A)(1) result in working spaces about electrical equipment that are considerably reduced from previous editions of the NEC. This reduction in working clearance in disallowed because it would result in a negative impact on worker safety.

21 LANL LIR 402-600-01, "Electrical Safety;" OSHA 1910.303(a); OSHA 1926.403(a); and NFPA 70-1999 Article 110-2 establish the requirement that electrical system and utilization equipment be acceptable to the AHJ.

22 LANL LIR 402-600-01, "Electrical Safety" establishes that NRTLs acceptable to the LANL AHJ are those "Organizations Currently Recognized by OSHA as NRTLs" on the OSHA website.

23 This National Electrical Code requirement is re-stated for emphasis.

24 Altitude at LANL ranges form 6250 ft at TA-39 to 7780 ft at TA-16. Elevation information is from USGS 1:24000 quadrant maps: Frijoles, NM and White Rock, NM.

25 IEEE Std 1015, "IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems", the ANSI C37 collection "Circuit Breakers, Switchgear, Substations, and Fuses", and the ANSI C57 collection "Distribution, Power, and Regulating Transformers" provide information about the de-rating effects of elevation on electrical equipment.

26 Climatology information (average temperatures, thunderstorm frequency, etc.) from "Brief Climatology for Los Alamos, NM" available at http://weather.lanl.gov/html/climatology.html. (A thunderstorm day is defined as a day on which thunder is heard or a thunderstorm occurs.)

27 Lightning flash density map for Los Alamos from Global Atmospherics, Inc. for 1/1/2001 to 12/31/2001.

28 IEEE 493 provides methods for quantitative reliability analysis as it applies to the planning and design of electric power distribution systems.

29 IEEE Std. 141-1993, Chapter 9 points to IEEE Std 519 for limits on the harmonic currents that a user can induce back into the utility power system.

30 DOE Office of Industrial Technologies Motor Tip Sheet #2, January 2000.

[31] NFPA 70-1999, Article 110 establishes minimum working clearances and dedicated spaces for electrical equipment.

[32] 29 CFR 1926.501(b)(1) requires fall protection when the working distance from the equipment is 6 feet or less; 10 feet minimum distance allows for equipment door swings and removal of equipment.

[33] Dedicated electrical rooms make it more likely that LANL will remain in compliance with the following 1999 NEC articles: 110-11, 110-13(b), 110-30, 110-31, 110-32, 110-33, and 110-35.

[34] Refer to Clause 1.15 in IEEE Std 241-1990 for additional building access and loading information.

[35] Voltage drop criteria are mandatory provisions in ASHRAE/IESNA Standard 90.1-1999.

[36] 100 ft is the approximate maximum circuit length serving a 120V 16-ampere, 0.95 pf line-neutral load through a magnetic conduit with 12 AWG conductors in a balanced multi-wire circuit or with 10 AWG conductors in a 2-wire circuit with 3% voltage drop.

[37] 230 ft is the approximate maximum circuit length serving a 277V 16-ampere, 0.95 pf line-neutral load through a magnetic conduit with 12 AWG conductors in a balanced multi-wire circuit or with 10 AWG conductors in a 2-wire circuit with 3% voltage drop.

[38] Vertical alignment facilitates installing economical feeders, sharing grounding electrode bars, transformers, etc.

[39] Having the panelboard on the same floor as the load reduces the number of customers disturbed when a panel must be de-energized for maintenance or modification.

[40] 60” vertical clearance above medium-voltage switchgear allows for the 51” offset of a 6” conduit elbow with 36” radius plus space for conduit hangers.

[41] The 48 inch clearance is calculated as follows: 5000A busway switchgear flanged end 10”, transition elbow 21”, edgewise busway centerline to top 13”, busway hanger and support rod 4”. This guidance is from lessons learned from several LANL installations that were very difficult due to inadequate vertical clearance above switchgear.

[42] Minimum clear distance based on 2002 NEC Table 110.34(A) using 7960 volts to ground (13,800 / 1.732) and Condition 2. Working space to allow thermographic examination with equipment energized.

[43] Based on medium-voltage switchgear manufacturers’ recommendations.

[44] Based on switchgear manufacturer’s recommendations based on removal/insertion of draw-out circuit breakers using a top-mounted breaker hoist.

[45] Working space to allow thermographic examination with equipment energized. Minimum clear distance based on 2002 NEC Table 110.26(A)(1) using 151-600 volts to ground and Condition 2.

[46] To enhance flexibility and expandability, the pre-1999 NEC dedicated space requirements for electrical equipment are retained for new LANL facilities. In existing facilities that are being renovated, the minimum current NEC dedicated space requirements are allowed.

[47] 2002 NEC Section 110.31(A) requirement, repeated here for emphasis.

[48] 2002 NEC Section 110.33 requirement extended to cover all electrical rooms.

[49] Lighting Design Guide in Chapter 10 of the Ninth Edition of the IESNA Lighting Handbook recommends 30 footcandles illuminance for industrial maintenance operations.

[50] Refer to maintenance illumination recommendations in clause 9.2.3 of IEEE Std 902-1996.

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[51] Article 400-8 in the 1999 NEC prohibits running portable cords through doorways; therefor, at least one receptacle outlet must be installed in each electrical room.

[52] Electrical room temperature limits from IEEE C57.12.00, IEEE C57.12.01, IEEE C37.20.1, and IEEE C37.20.3.

[53] Recommended practice from Chapter 3 of NECA 400-1998, adapted to medium-voltage equipment.

[54] LIR/LIG 402-100-01, Signs, Labels, and Tags; 1999 NEC Articles 110-21 and 110-22; and the 1999 New Mexico Electrical Code paragraph 10.1.1.

[55] The code tag uniquely identifies the equipment item.

[56] The code tag should be large enough to be easily read while standing on the floor. The code tag is such that it can be made in the field on adhesive material using a commercial label-making machine.

[57] Category I nameplates are essential to the efficient implementation of the LANL lock-out/tag-out program.

[58] Safety-related operating or maintenance instructions are required by NFPA 70E-2000, part III, chapter 2, paragraph 2-8.

[59] Safety-related emergency instructions are required by NFPA 70E-2000, part III, chapter 2, paragraph 2-8.

[60] The equipment nameplates can be made in the field on adhesive material using a commercial label-making machine.

[61] Voltage identification is required by NFPA 70E-2000, part III, chapter 2, paragraph 2-10.

[62] Warning signs are required by NFPA 70E-2000, part III, chapter 2, paragraph 2-9.

[63] Refer to section 110.16 in the 2002 NEC.

[64] Identification of components of an emergency power system is required by 1999 NEC Article 700-9.

[65] Labeling of outlets and switches to indicate circuit is a long-standing practice at LANL to facilitate maintenance and lock-out/tag-out.

[66] Labeling of conductors is a long-standing practice at LANL to facilitate trouble-shooting of systems.

[67] Marking of the NEC required clear space at electrical equipment helps keep facility users from using these areas for storage.

[68] NFPA 70B-1994, paragraph 4-2.3, Recommended Practice for Electrical Equipment Maintenance, strongly recommends having system diagrams, operating instructions, and emergency procedures readily available.

[69] DOE- STD-1020 requires seismic protection based on the assigned PC level. LANL Spec 13085 provides seismic protection measures for mechanical and electrical equipment.

[70] NECA 400, Recommended Practice for Installing and Maintaining Switchboards.

[71] By gnawing, mice can gain entry through openings larger than 1/4 inch. Refer to “Rodent Exclusion Techniques” pamphlet published by the National Park Service in 1997.

[72] Refer to “Rodent Exclusion Techniques” pamphlet published by the National Park Service in 1997.

[73] LANL institutional policy developed through observation and experience. Removal of abandoned equipment, outlets, wiring, and raceways will have positive safety benefit for maintenance and operations personnel; in addition it will reduce the clutter and obstructions in LANL facilities.

[74] LANL institutional policy developed through observation and experience. Describes extent and limits of demolition work.

[75] The logic in 1999 NEC Article 300-21 for preventing the spread of fire and products of combustion is extended from new construction to demolition.

[76] LIR402-600-01, Electrical Safety, applies to D&D work.

[77] Refer to LANL AHJ memo dated February 13, 1995, Subject: Electrical Safety in Demolition Work and Remodeling Projects.

[78] *The NETA Acceptance Testing Specifications* (ATS) is a document to assist in specifying required tests on newly-installed electrical power systems and apparatus, before energizing, to ensure that the installation and equipment comply with specifications and intended use as well as with regulatory and safety requirements. *The Acceptance Specifications* include topics such as Applicable Codes, Standards, and Reference; Qualifications of the Testing Agency; Division of Responsibility; General Information concerning Testing Equipment; Short-Circuit Analysis and Coordinating Studies, System Function Tests; and Thermographic Surveys. The ATS includes tests to be performed on Switchgear and Switchboard Assemblies, Transformers, Cables, Metal-Enclosed Busways, Switches, Circuit Breakers, Network Protectors, Protective Relays, Instrument Transformers, Metering and Instrumentation, Grounding Systems, Ground Fault Systems, Rotating Machinery, Motor Control, Direct-Current Systems, Surge Arresters, Capacitors, Outdoor Bus Structures, Emergency Systems, Automatic Circuit Reclosers and Line Sectionalizers, Fiber-Optic Cables, and Electrical Safety Equipment.

[79] Certification is a means for individuals to indicate to employers, co-workers, the general public, and others that they have met the standards of an impartial, nationally-recognized organization for the performance of specific technical tasks by virtue of their technical knowledge and experience. An Electrical Testing Technician (ETT) performs tests and inspections and evaluates the suitability of electrical power equipment and systems for the intended use. Inherent in the determination of the serviceability of electrical equipment is the prerequisite that individuals performing these tests be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must also evaluate the test data and form an opinion on the continued serviceability or non-serviceability of the specific equipment. The evaluation of service-aged equipment requires subjective assessment by the ETT. Therefor, specifying requisite levels of training, experience, and education for the evaluator of electrical power equipment is as important as the test procedure itself. The requirements in ETT-2000 parallel those of the National Skill Standards Board in Washington, DC, which promulgates skill levels for various occupations.

[80] Refer to section 80.19(F) in the 2002 NEC.

[81] DOE O 420.1, ”Facility Safety,” requires safety analysis in accordance with DOE guidance documents.

[82] DOE G 420.1-1 provides an acceptable approach for satisfying the requirements of DOE O 420.1.

[83] DOE O 420.1, Section 4.1.1.2 requires that safety class electrical systems be designed to the basic approach outline in Section 5.2.3 of DOE G 420.1-1.

[84] From DOE G420.1-1, “Implementation Guide for Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria,” section 5.2.3 Electrical.

[85] Adapted from DOE G420.1-1, “Implementation Guide for Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria,” Tables 5.5 and 5.6.